Structural Stability of Stimson Cooling Pond Embankment
Preliminary Engineering Analysis

Prepared for: Dept of Justice

Prepared by: Dept. of Natural Resources and Conservation

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This report presents the conclusions and recommendations made by a team that was tasked with predicting the performance of the Stimson cooling pond embankment after removal of the Milltown Dam. The team used computer models to assist in their evaluations. The models were used to estimate the water surface elevation and velocity of the Blackfoot River in the area of the cooling pond without backwater from the Milltown dam. Models were also used to predict the stability of the cooling pond embankment, both short term and long term.

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Executive Summary

INTRODUCTION

In the early 1900's, the Stimson Lumber mill created an embankment for plant cooling water that extends partway into the Blackfoot River.   Upon removal of the Milltown Dam, upstream water levels in the Blackfoot River in the area of the cooling pond embankment will be lower.   There is some uncertainty as to how the cooling pond embankment will perform with less tail water on the Blackfoot River side of the embankment.

The Dept. of Natural Resources and Conservation (DNRC) was asked by the Dept of Justice (DOJ) to do a cursory engineering analysis of the embankment stability, and make recommendations for future action. DNRC put together a team of scientists to run a variety of computer models to help predict future performance of the cooling pond embankment, once the Milltown Dam is removed.

This report is divided into four components:
1) <u>Construction of the Cooling Pond Embankment</u>: There are no documents that describe the construction of the cooling pond embankment. Visually, it appears to be a mixture of both soil and timber cribbing.   The team evaluated turn of the century photos and conducted a visual reconnaissance of the site to estimate how the embankment was constructed and its composition.
2) <u>Water Surface Elevations in Blackfoot River</u> – Post Milltown: The Milltown dam backs up water into the Blackfoot River.   With the Milltown dam removed, the water levels in the Blackfoot will be much lower. The team ran a model of the Blackfoot River for a variety of flow events to determine the water level and velocity of the Blackfoot River in the area of the cooling pond embankment
3) <u>Stability of Cooling Pond Embankment (Long term and short term)</u>: With Milltown dam in place, the majority of the downstream face of the cooling pond embankment is under water.   Post dam removal will expose a significant portion of the downstream face of the dam, which may affect embankment stability, both statically and from erosional forces of the river.   The team evaluated a variety of slope stability models to help determine if the embankment will remain stable.
4) <u>Conclusions and Recommendations</u>: This section of the report summarizes the conclusions made by the team and recommendations for future action.

COOLING POND EMBANKMENT CONSTRUCTION

There are several uncertainties regarding embankment construction. A visual inspection of the cooling pond revealed that part of the embankment was comprised of soil and part of the embankment is comprised timber cribbing.   A geotechnical investigation involving exploratory drilling would reveal the extent of the timber cribbing, condition of the foundation materials, location of the phreatic surface through the embankment and strength of embankment soils.   However, for this preliminary level of investigation, exploratory drilling was not authorized.

A comparison of historical and current photos suggested that the embankment was built on top of existing timber crib structures located within the Blackfoot River (Refer to Figures 1 - 4)


Figure 1: View of Stimson Dam, pre-dam removal (November, 2005)

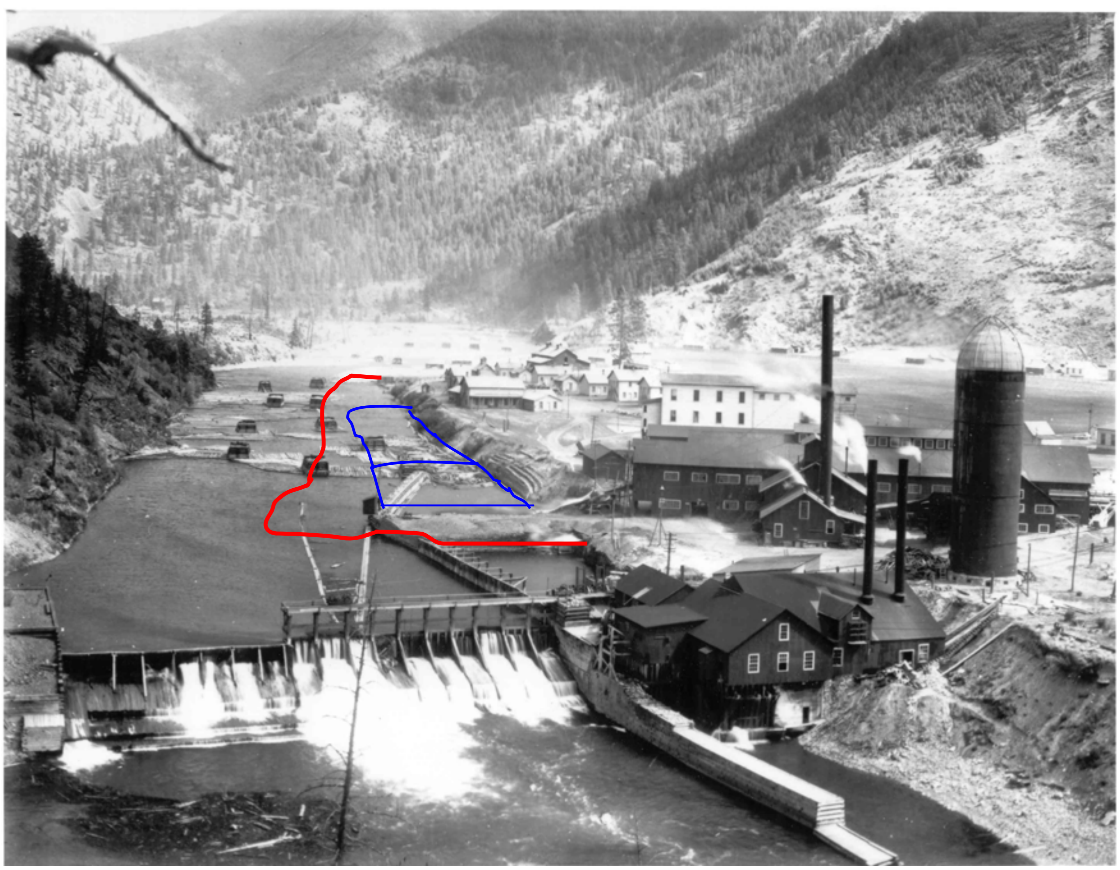
Figure 2: Stimson dam, 1900's with cooling pond embankment projected

Figure 3: Mid River Crib Structure – Similar crib structures as shown in Figure 1 & 2 were believed to be used as base structures for cooling pond embankment

Figure 4: Embankment Crib structure. It appears that the old mid river cribs shown in Figure 1 were filled in with soil and rock and a new timber crib structure built on top.

A visual analysis of the embankment conducted in October 2005 supports this conclusion, as shown in Figure 5.

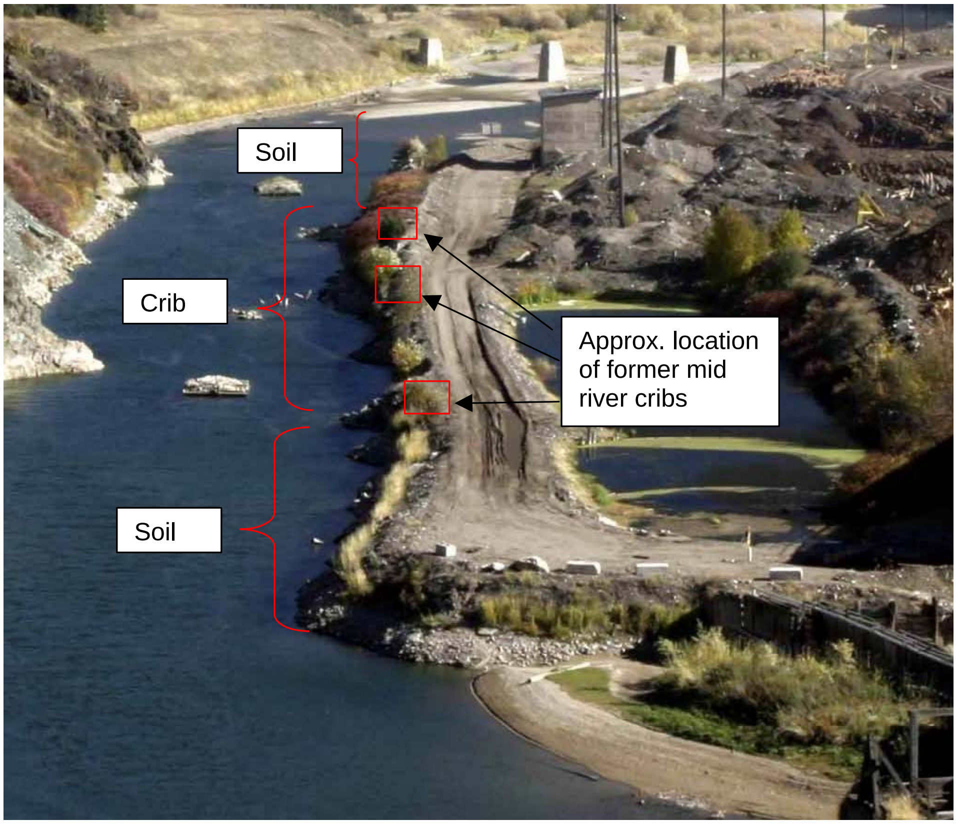

Figure 5: Suggested embankment construction superimposed on photo of cooling pond embankment

WATER SURFACE ELEVATIONS IN BLACKFOOT RIVER

Two water surface profile models of the Blackfoot River were developed by the consulting firm EMC^2 to evaluate scour potential at the I-90 bridges. The team used these same models to predict water surface elevations in the area of the cooling pond embankment with the Milltown dam removed. Slight modifications were made to the model to include recent survey data of the cooling pond embankment. Other modifications to the models are described in Appendix I. Table 1 lists the flow events that were modeled and the question to be answered. Three areas of the embankment were targeted for evaluation, as shown in Figure 6.

Table 1. Modeled flow events

Flow Event	Question to be answered
100-yr return interval Blackfoot River; 25-yr return interval ClarkFork River	Does cooling pond embankment overtop during a flood event?
Average low flow both rivers (post runoff)	What is typical water surface elevation at cooling pond embankment mid summer and do velocities present a problem?
Bank full both rivers (1.5 year return interval)	What is typical water surface elevation in spring and do velocities present a problem?
Winter flow both rivers (10 year return interval)	What is typical water surface elevation in winter with ice jamming and do velocities present a problem?

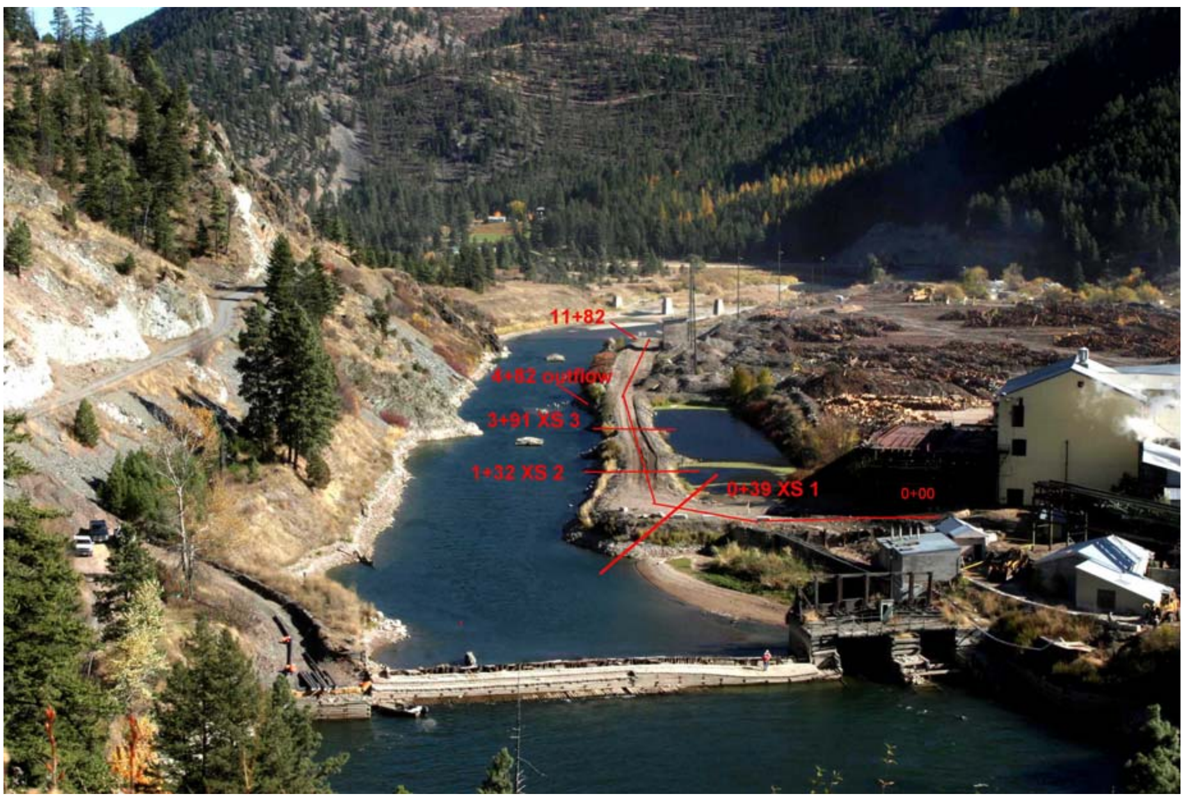

Figure 6 Stationing and location of embankment cross-sections that were evaluated. The embankment is believed to primarily soil in cross sections 1 & 2. Cross Section 3 is primarily timber crib.

The results obtained from the modeling are summarized below for cross section number 3, which is located in the timber crib portion of the embankment.

<u>100 year flow Blackfoot River; 25 year flow Clark Fork River</u>

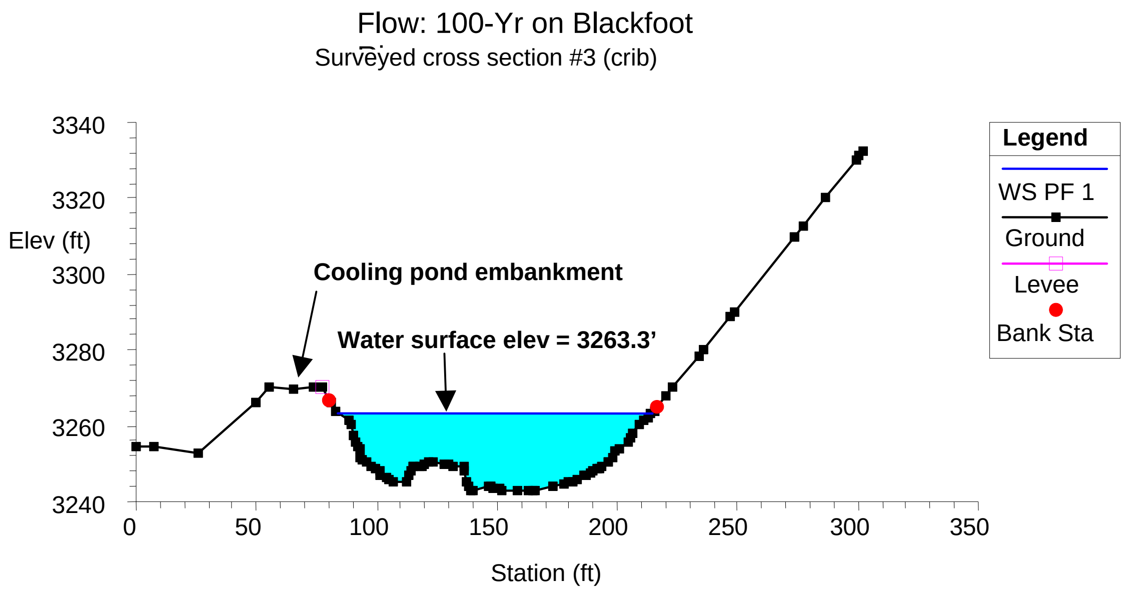

Figure 7. With Milltown dam removed, the water surface of the Blackfoot River does not overtop the embankment.

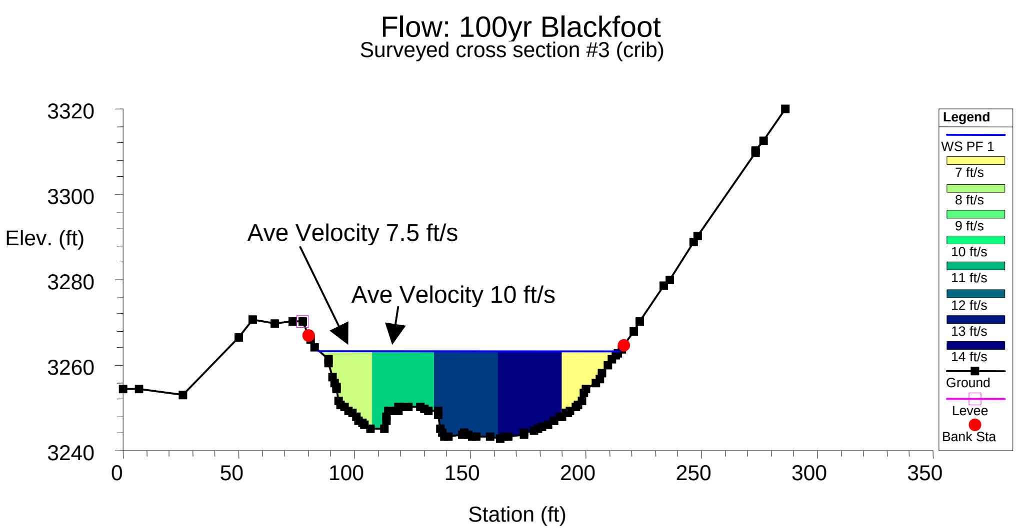

Figure 8. Velocity Distribution for 100 yr flow on Blackfoot at Cross section #3. Velocities in excess of 6 ft/s can be transport sediment.

Average Low Flow for both Blackfoot River and Clark Fork River

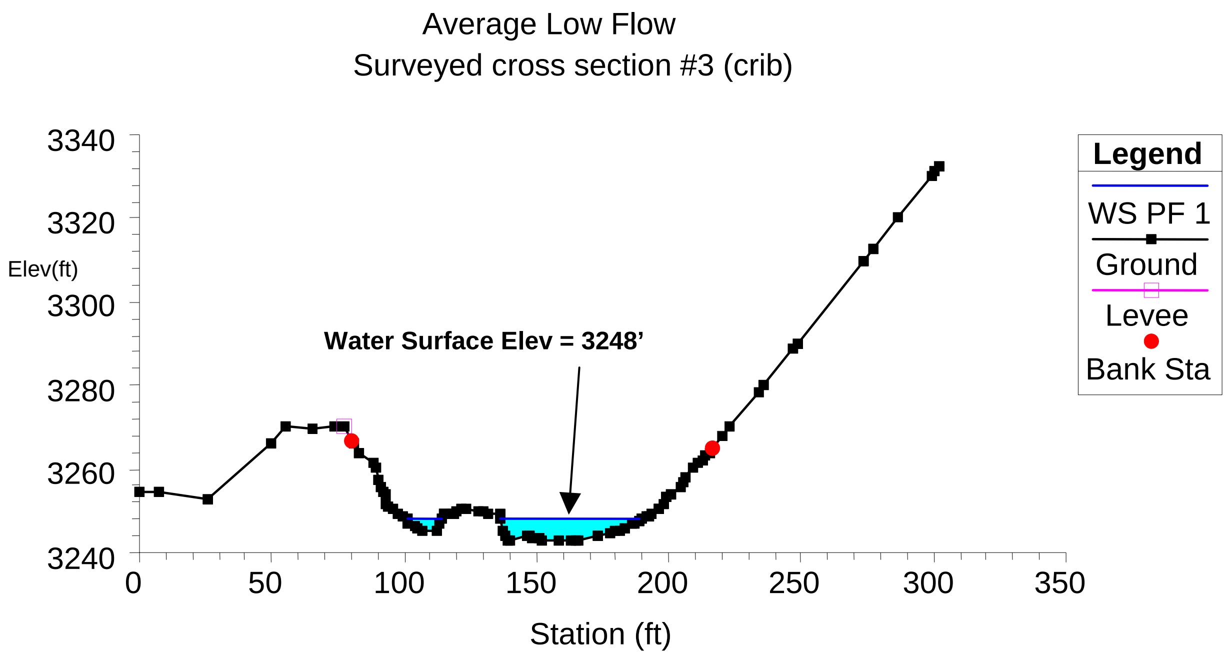

Figure 9. Water surface elevation for average low flow at cross section 3

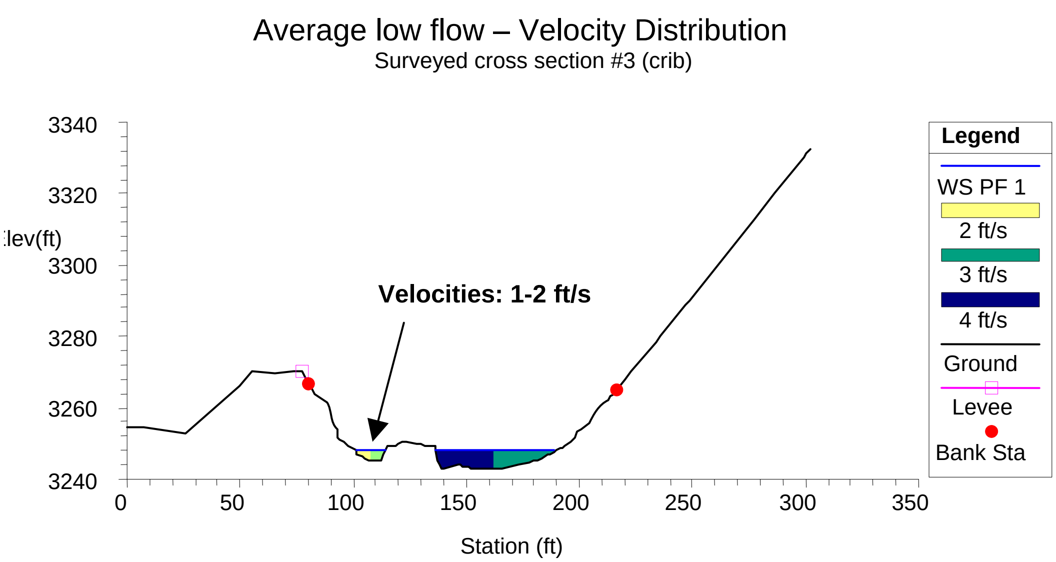

Figure 10. Velocity distribution for average low flow at cross section 3. Velocities are too low to cause significant scour and transport of sediments.

Bank Full for both Clark Fork River and Blackfoot River

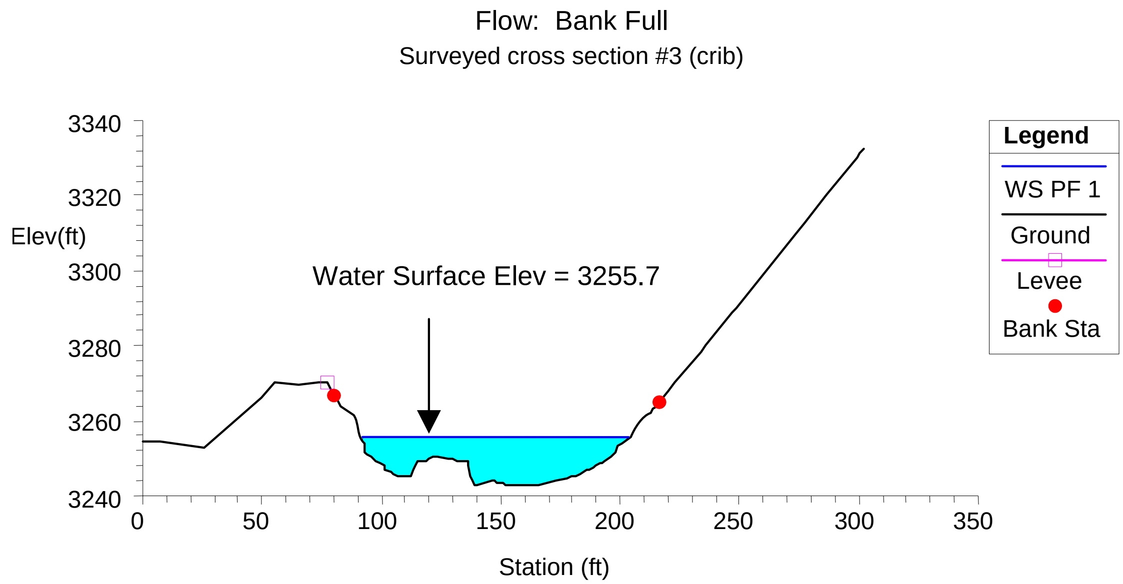

Figure 11. Water surface profile for bank full flow at cross section 3. "Bank Stations" shown on model reflect bank full stations prior to removal of Mill town Dam.

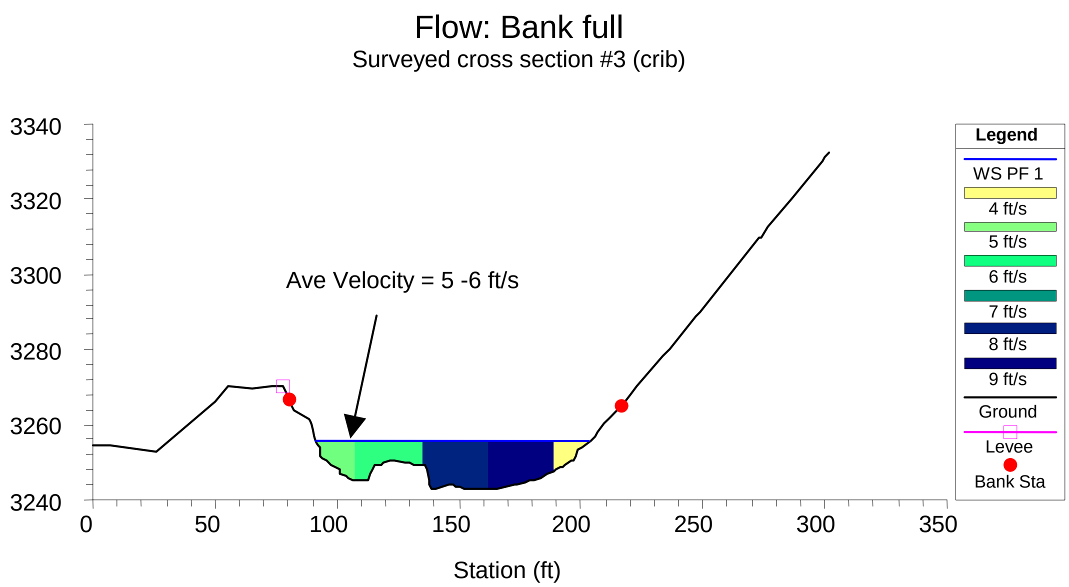

Figure 12. Velocity distribution at cross section #3 with bank full conditions. Scour and transport of sediments can initiate with velocities in this range

Winter Flow both Blackfoot & Clark Fork (10 year)

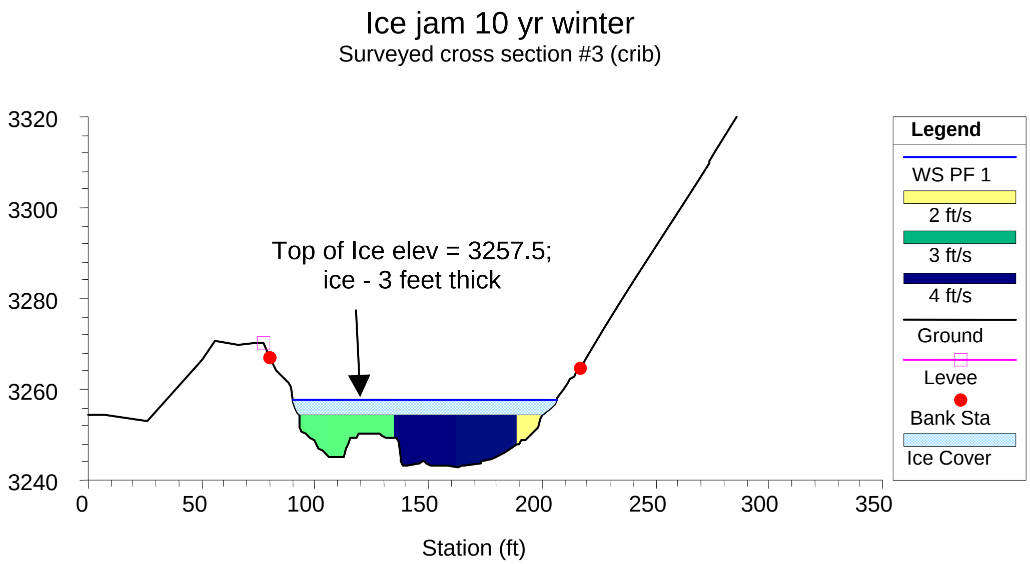

Figure 13. Water Surface and velocity distribution for 10-year winter flow event with ice jamming on Blackfoot River. Cooling pond embankment is not overtopped. Ice is gets up to 3 feet thick. Velocities remain low.

STABILITY OF COOLING POND EMBANKMENT

With the Milltown dam in place, substantial tailwater exists on the riverside of the cooling pond embankment. Tailwater is a stabilizing force on a dam. There is some question how the embankment will perform with future lower tailwater once Milltown is removed. In addition, the timber crib portion of the embankment has historically been mostly under water. Timbers can last a very long time under water. However, once the timbers are exposed to air, they are known to deteriorate rapidly. Thus, the stability of the embankment with deteriorating timbers must be evaluated. Finally, with lower water levels in the Blackfoot, potential for scour and erosion on the embankment will change. How this could affect embankment stability must be examined.

Static Stability of Embankment

A conceptual model was developed to analyze stability of the cooling pond embankment using a limit equilibrium static slope stability model. Exploratory drilling was not within the scope of this preliminary analysis. As a result, assumptions had to be made based on a visual field reconnaissance and surface soil samples. The original intent of the model exercise was to determine if the embankment met current industry required safety factors. However, it became clear that there were too many unknowns to confidently report a range of probable safety factors. Figure 14 shows the conceptual model and the variables needed to evaluate embankment stability.

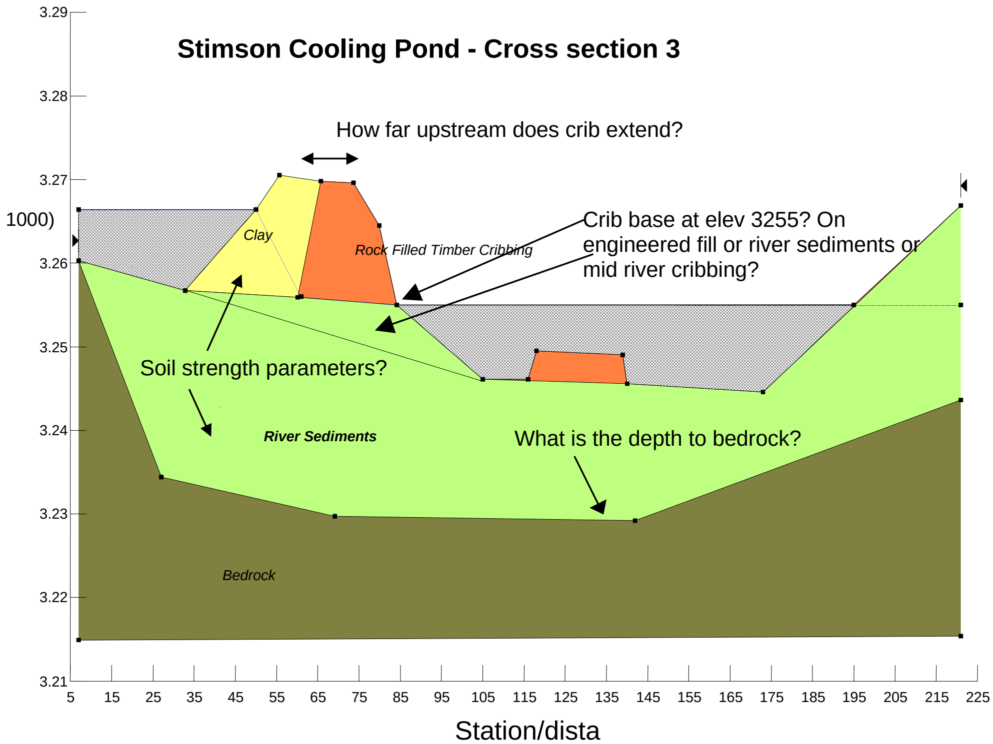

Figure 14. Conceptual model of cooling pond embankment at cross section #3 (timber crib area) highlighting the missing information necessary to adequately quantify stability.

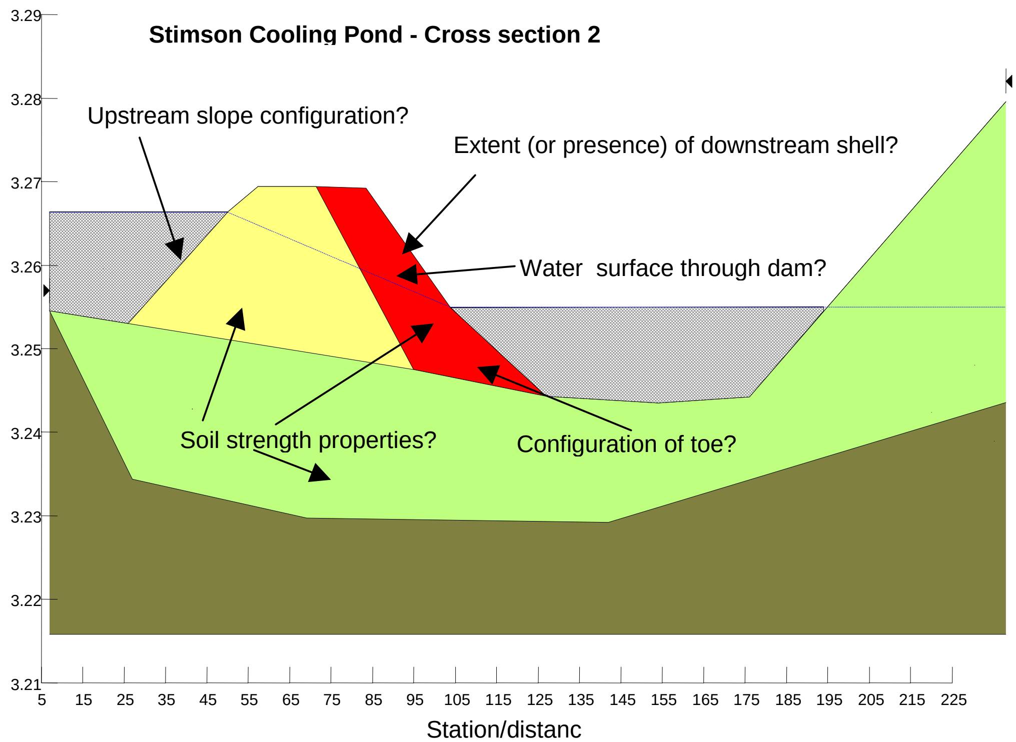

Figure 15. Conceptual model of cooling pond embankment at cross section #2 (soil embankment) highlighting the missing information necessary to adequately quantify stability

In spite of the missing information, a number or observations could be noted:

1. The base of the timber cribbing in locations where the mid river cribs are suspected to be absent appeared to be at elevation 3255 ft.
2. During our site visit in October, the Blackfoot River was drawn down to elevation 3255 ft. The pond remained at a virtually constant level. Therefore, it is reasonable to assume the upstream section of the embankments consists of low permeable clay soils, which is consistent with surface soil samples obtained at the site. Figure 16 shows the upstream face of the dam in the area of cross section 3. The upstream face appears to be gently sloping clay soils
3. The downstream face of the dam was unsaturated, and showed no evidence of seepage.   Therefore, it is reasonable to assume the downstream section of the embankment and cribbing is very free draining. Most likely the cribbing is rock filled, and the embankment has a gravel rock shell. Figure 17 shows the downstream face of the dam in the area of cross section #2
4. Rough runs of the conceptual models using estimated strength parameters indicates that tailwater is not a significant factor in static stability.
5. Rough runs of the conceptual models using estimated strength parameters show that the embankments in their current configuration may not meet industry accepted safety factors.
6. Rough runs of the conceptual models using estimated strength parameters show the embankment stability is most sensitive to level of phreatic surface through the dam.
7. There was evidence of deterioration of timber crib that has been above or right at Blackfoot River water levels with Milltown dam in place (Figure 18).   It is reasonable to assume that timber cribbing that will newly be exposed will rapidly deteriorate.

Figure 16. Upstream face of embankment in area of cross section #3. Note gentle slope.

Figure 17. Downstream “shell” of soil embankment in area of cross-section #2

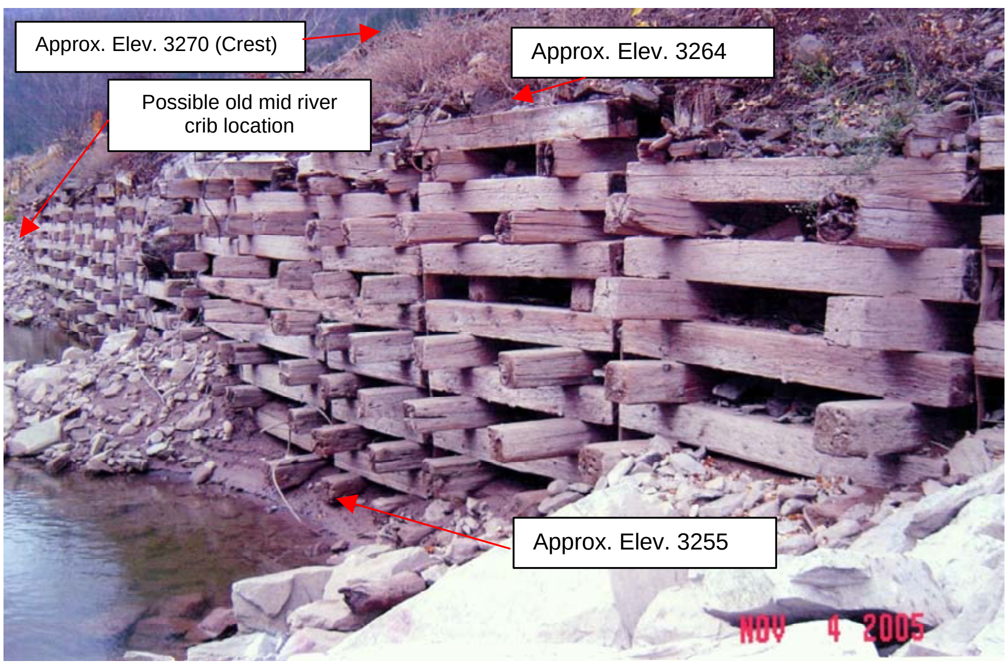

Figure 6: Timber crib section of cooling pond. With Milltown dam in place, the water surface elevation of the Blackfoot River is at elevation 3262 ft. In this photo, water was drawn down for removal of the Stimson dam.

Erosional Stability of Embankment

The team looked at the results from the water surface profile modeling as well as a visual reconnaissance of the dam and survey data and made the following observations:

- There is a high potential during non-uniform flow for local acceleration and scour at new lower water levels
- There is significant potential for erosion of the toe during the 100-year event.
- With flows bankfull and higher, there is potential for eddying
- At bankfull, there is potential for undercutting of crib
- The exposed wood will likely see a breakdown in 5-10 years
- The river will see local acceleration at the bend upstream of the pond right at the river constriction.
- During an ice jam, the timber crib is more at risk from damage then in past
- The embankment will need to be stabilized using buttresses and riprap.

CONCLUSIONS

The team made the following significant conclusions (post dam removal):

1. The embankment does not overtop at 100 year flow
2. The water level in the Blackfoot River will be 7' lower for bankfull conditions and 14' lower for average flow conditions
3. Ice jams will not overtop the embankment as in past; however ice jams will be at a critical location with potential to damage timber cribbing
4. The toe of the embankment is at risk for erosion when the river is bankfull. Undercutting of the timber crib is possible.
5. The embankment may not meet current industry accepted safety factors. Additional geotechnical investigation is necessary.
6. There is a need for further investigation of the embankment and foundation: extend of timber cribbing (laterally and vertically), soil strength, embankment construction, depth to bedrock, foundation characteristics, upstream slope configuration, and phreatic surface through embankment.
7. Pond is currently not permitted according to the Navigable River Use Permit. If the pond stays in place, a permit will be required.
8. Bobcats deserve to win

RECOMMENDATIONS

The team made the following recommendations:

1. The embankment should be removed and relocated for the following reasons:
    a. There is strong potential for undercutting of timber crib at bankfull conditions; there is also strong potential for erosion of the toe.
    b. There is potential for ice damage to the timber crib, that wasn't present in the past.
    c. The timber cribbing is expected to dramatically deteriorate in the next five years, presenting stability problems
    d. The embankment may not meet required safety factors

2. If Stimson would like to leave the embankment in place the following should be required:
    a. The embankment must be permitted.
    b. A thorough geotechnical investigation must be completed and an evaluation of embankment stability done.
    c. Upgrades to the embankment such as buttressing and the addition of riprap to prevent erosion and undercutting at bankfull conditions will be necessary. This will require Stimson to obtain additional permits (310 permit, Floodplain permit, COE 404 permit, etc.) allowing work to be conducted within the river.
3. A cost evaluation of alternatives is necessary. It is likely that finding an alternate location for the cooling pond will be more cost effective than upgrading, evaluating and permitting the existing structure.
4. Stimson must make a decision as to a course of action by Feb 1, 2007.

APPENDIX I
WATER SURFACE PROFILE MODELING INPUT AND OUTPUT

The attached CD contains 7 HECRAS (Hydrologic Engineering Center River Analysis System, 2005) model runs. The CD also contains a table with flow data from a variety of flow events (provided to DNRC by EMC[2]).

Table 3 describes each run.

Run #	**Manning n (near embankment)**	**Flow BFR**	**Flow CFR**	**Comment**
1	0.06 (from original model)	100 year	25 year	
2	0.03 (believed to be more realistic by team)	100 year	25 year	
3	0.03	Ave. low flow	Ave. low flow	
4	0.03	Bank full	Bank full	
5	0.03	Winter event – 10 year	Winter event – 10 year	
6	0.06	100 yr	25 yr	Original model ran as a mixed flow regime to see if error at downstream bridge causes problem[1]. No significant change in upstream water surfaces detected.
7	0.06	100 yr with ice jam	25 year	

1 Original model ran as subcritical flow regime. At downstream bridge, flow goes supercritical. In a subcritical flow regime, flow cannot go supercritical and water surface profile defaults to critical depth. This may or may not be accurate and has potential to affect upstream water surfaces. Program was run using mixed flow with normal depth as upstream boundary conditions to see if defaulting to critical depth is a problem.

<u>Notes on Modifications to Model made by DNRC</u>

1. Spliced river stations incremented with channel length – doesn't match direct conversion of river stations from remediation model in miles to feet (doesn't affect calculations)
2. Cross sections didn't extend over cooling pond…artificially extended 50-80 ft using data surveyed by DOJ, DNRC. River schematic adjusted 50 ft (approx 15 m) in y direction, assume base map in UTM coordinates.
3. Conveyance errors in original geometry and revised geometry. Cross section modified to remove in stream structures – no effect. Reevaluation of geometry with

additional surveyed cross sections may be necessary to determine cause of conveyance errors.

4. Change between upstream not modified cross section and downstream new cross section seems a bit radical, but no errors in this location. This needs to be evaluated.
5. Station 847 (original data) goes supercritical in subcritical model

APPENDIX II
SLOPE STABILITY MODELING INPUT AND OUTPUT

The attached CD contains the following conceptual models developed using the software Slope/w for the cooling pond embankment:

XS3_Crib conceptual.slz
XS2_Soil embankment conceptual.slz
XS2_soil embankment lower_tw.slz